Name : .....

Roll No. : .....

Invigilator's Signature : .....

CS/M.TECH (BT)/SEM-1/MBT-115D/2011-12

2011

ADVANCES IN BIOREACTOR DESIGN, DEVELOPMENT AND SCALE-UP

Time Allotted : 3 Hours *Full Marks* : 70

The figures in the margin indicate full marks.

Candidates are required to give their answers in their own words as far as practicable.

GROUP – A

(Multiple Choice Type Questions)

1. Choose the correct alternatives for any *ten* of the following : $10 \times 1 = 10$

i) A reactor may be assumed as plug flow if the flow is

a) laminar b) turbulent

c) streamline d) viscous flow.

ii) RTD curve due to pulse input gives rise to

a) asymptotic curve

b) hyperbolic curve

c) bell-shaped curve

d) normal distribution curve.

iii) Volumetric mass transfer coefficient, K_{La}, for Bubble column is given as a function of

a) P/V

b) V_{gs}

c) Re_I

d) Combination of (a) & (b).

iv) Anti-biotics are best produced in ..... , type of the reactor.

a) Packed bed b) Bubble column

c) CSTR d) Air-lift fermenter.

v) The kinetics of vaccine production is based on the model of

a) growth associated

b) non-growth associated

c) a combination of (a) and (b)

d) Monod model

vi) Low flow rate of a gas is measured by

a) rotameter b) Orificemeter

c) wet gas meter d) thermo-anemometer.

vii) Trickel bed reactor is characterized by

a) mass transfer

b) low L/D ratio

c) combination of (a) and (b)

d) small flow rate of liquid.

viii) Cell suspension is a non-Newtonian fluid of the type

a) Bingham plastic b) Pseudo plastic

c) Dilatant d) Cassar equation.

ix) Monod Model behaves as a reaction of the ..... type for small substrate concertration.

a) first order b) zero order

c) second order d) pseudo first order.

x) Perfusion reactor is used for the production of

a) antibiotics

b) alcohol

c) monoclonal antibodies

d) single cell protein.

xi) The criterion for the selection of animal cell culture reactor is

a) low shear rate

b) removal of toxic metaolites

c) combination of (a) and (b)

d) high cell mass concentration.

xii) The scale-up criterion for a CSTR to be used for animal cell culture is based on

a) geometric similarity

b) equal P/V

c) equal tip velocity

d) equal impeller based Reynolds No., Re_I

GROUP – B

(Short Answer Type Questions)

Answer any *three* of the following. 3 × 5 = 15

2. In a CSTR, efficient mixing is achieved if the eddy size, created by a turbine impeller is approximately 80 μm. The impeller diameter, D_I = 0·3 m.

   Calculate the power to be generated by the stirrer for desired degree of mixing. Given, $\lambda = \left(\frac{\gamma}{\square}\right)^{1/4}$, where γ is the kinematic viscosity of the liquid, $\square$ is the energy dissipated per unit mass of the fluid.

   $\mu = 1 \infty 10^{-3}$ Pas and ρ (density) = 1000 kg/m^3.

3. Describe the important features of a stirred tank reactor with respect to efficient mixing.

4. The scaled-up volume of a reactor is 100 m^3 from 0·1 m^3 reactor with L/D = 3. The impeller diameter, D_I = 0·3 D.

   If the agitator speed of the small reactor is 600 rpm, what is the agitator speed of the bigger reactor, on the basis of equal mixing time, t_m ?

5. At room temperature sucrose (A) is hydrolysed by the enzyme sucrase (E) as follows :

$$A \xrightarrow{\text{Enzyme}} \varnothing \text{ products}$$

Given data :

C_A (mol./m^3)	0·68	0·16	0·006
t, hr	2	6	10

At $t = 0$, $C_{Ao} = 1{\cdot}0$ mole/m^3 , $C_{Eo} = 0{\cdot}01$ mole/m^3 .

The rate equation is $\dfrac{-dC_A}{dt} = \dfrac{V_{max} C_A}{k_m + C_A}$

Linearise the rate equation after integration to find v_{max} and k_m (the kinetic parameters) .

6. Derive the following relation from Michaelis-Menten Enzyme kinetic relation :

$$V_{max}\ t = S_o - S + k_m\ ln\ S_o / S$$

GROUP – C

(Long Answer Type Questions)

Answer any *three* of the following. 3 × 15 = 45

7. a) A Bubble Column reactor of volume 1 m^3 $\left(\dfrac{L}{D_t} = 5 \right)$ is agitated by sparging air from the bottom at the rate of 0·02 m^3 /s at 1·08 bar and 25°C. The santer mean diameter of bubbles is D_{32} = 3 mm and hold-up, ε_G = 0·05. Calculate the following

i) bubble rise velocity, m/s

ii) interfacial area, a (m^2 / m^3)

iii) volumetric mass transfer coefficient, k_{La}, given $k_{La} = 0{\cdot}32 (v_{gs})^{0.7} \text{ sec}^{-1}$.

b) Describe the operation of an air-lift fermentor which is to be used for animal cell culture. 8 + 7

8. a) How do you correlate the cell mass growth with oxygen consumption in terms of kinetic parameters and volumetric mass transfer coefficient k_{La} ?

b) The volumetric mass transfer coefficient, k_{La} of a small bubble column reactor (2 L) has been measured as 15 hr^{-1} at an airflow rate of 4 l/min. If the rate of oxygen uptake by a culture of some plant cells is 0·2 mmol (g.dry wt) (hr) and the critical oxygen concentration is 10% of the saturation (8 ppm). What is the maximum concentration of cells that can be maintained in the reactor ? 7 + 8

9. a) What are the methods of modelling non-ideal reactors ? Describe the tanks-in-series model with its performance equation assuming first order kinetics.

b) What are the merit and demerits of a hollow fibre reactor for animal cell culture ? 8 + 7

10. a) What is power law model to be used for Non-Newtonin fluids ? Classify the types of Non-Newtonian fluids by drawing shear stress (τ) and shear rate (γ) diagram.

b) Small laboratory PFR gives 80% conversion of A for a first order reaction of the type, $A \varnothing R$, with residence time, T = 15 mins. If the same reaction is carried out in a large reactor whose tracer date due to pulse input tracer gave σ_B^2 = 0·2 and E = 15 min. Calculate X_A from dispersion model for small deviation for plug flow.

7 + 8

11. a) An enzyme has a k_m of $4{\cdot}7 \infty 10^{-5}$ M. If the V_{max} of the preparation is 22 μ mole/lit min. What velocity would be observed in the presence of $2 \infty 10^{-4}$ M substrate and $5 \infty 10^{-4}$ M of (a) a competitive inhibitor, (b) a non-competitive inhibitor, (c) an uncompetitive inhibitor k_i in all three cases is $3 \infty 10^{-4}$ M. (d) What is the degree of inhibition in all three cases ?

b) What is the relative acivity and degree of inhibition caused by a competitive inhibitor when [S] = k_m and [I] = k_i ? 10 + 5

12. a) One microgram of a pure enzyme (MW = 92,000) catalyzed a reaction at a rate of $0{\cdot}50$ μ moles/min under optimum conditions. Calculate (a) the specific activity of the enzyme in terms of units/mg protein and units/mole, and (b) the turnover number, (c) how long is one catalytic cycle ?

b) An enzyme was assayed at an initial substrate conc. of $2 \infty 10^{-5}$ M. In 6 min. half of the substrate had been used. The k_m for the substrate is $5 \infty 10^{-3}$ M. Calculate k, v_{max} and conc. of product produced after 15 min.

c) $A \varnothing R$, $-r_A = \dfrac{200\, C_A C_{Eo}}{2 + C_A}$, in a batch reactor

C_{Eo} = $0{\cdot}001$ mol/lit, initial enzyme conc.

C_{Ao} = 10 mol/lit.

Time required for the conc. of reactant to drop to $0{\cdot}025$ mol/lit. 5 + 5 + 5